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of the

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

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NATIONAL DEFENSE RESEARCH COMMITTEE
of the
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

OXYGEN PLANT DEVELOPMENT
EMPLOYING REGENERATIVE CHEMICALS

to
March 16, 1945
by
W. E. Lobo and C. Bockius

Report OSRD No. 5154
Copy No. 33
Date: May 31, 1945

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NATIONAL DEFENSE RESEARCH COMMITTEE
of the
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

Section 11.1

OXYGEN PLANT DEVELOPMENT
EMPLOYING REGENERATIVE CHEMICALS

Service Directive NL-B42; NS-117

Endorsement (1) from H. M. Chadwell, Chief Division 11
to Dr. Irvin Stewart, Executive Secretary of the National
Defense Research Committee. Forwarding report and noting:

> "This report covers oxygen generating plants
> utilizing the absorbent "Salcomine." The
> plants were designed by the M. W. Kellogg Co.
> and such construction as took place was done
> by the American Machine Defense Corp. The
> shipboard unit, though completed, was super-
> seded by one designed and constructed by the
> A. D. Little Co. (Now installed on a Naval
> Vessel). The truck-mounted units were early
> abandoned as non-competitive with liquifaction
> units. Other units were largely experimental.
> This work was completed about two years ago."

This is a progress report under Contract 11-244, OEM-r-365
with M. W. Kellogg Co. and a final report under Contract
11-261, OEMsr-499 with American Machine Defense Corporation.

Final Report
On
Oxygen Plant Development
(Employing Regenerative Chemicals)
To
National Defense Research Committee
By
The M. W. Kellogg Company
Contract No. OEM-sr-365
And
American Machine Defense Corporation
Contract No. OEM-sr-499

Submitted by:

Walter E. Lobo

Walter E. Lobo
for
The M. W. Kellogg Company

C. Bockius

C. Bockius
for
American Machine Defense Corporation

March 16, 1945

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SUMMARY

This report contains a description of the work performed by The M. W. Kellogg Company and the American Machine Defense Corporation for the National Defense Research Committee in the development of oxygen plants employing regenerative chemicals.

In addition to a chronological description of each plant or study involved in the program, the roport contains a bibliography of correspondence, memoranda, reports and specifications dealing with equipment details and operating experiments.

Detailed procoss calculations and a list of all drawings are supplied for the Shipboard (C-2) unit, the only complete unit fabricated by the contracting companies. Process calculations and detailed designs are not furnished for plants which were studied but not erected.

GENERAL DESCRIPTION OF WORK

Preliminary Activities

In December, 1941, exploratory discussions were held between representatives of the National Defense Research Committee and The M. W. Kellogg Company. In the following month, January, 1942, Kellogg formally agreed to become the central engineering agency for the NDRC oxygen program. On January 27, Kellogg representatives attended a general conference on oxygen problems convened at Massachusetts Institute of Technology under the sponsorship of the NDRC oxygen section.

At this meeting it was made clear that high hopes were entertained for mobile oxygen plants based on the use of the regenerative chemical "Salcomine". Preliminary engineering studies by Dr. Gilliland's group at M.I.T. had indicated that attractive yields of oxygen could be absorbed from the atmosphere by beds of Salcomine undergoing what then seemed to be moderate changes of temperature and pressure.

During February negotiations were carried on between the NDRC and the American Machine & Foundry Co., which finally culminated in the granting of a contract to the American Machine Defense Corporation, a newly formed subsidiary of American Machine & Foundry Co. Kellogg meanwhile began process and equipment studies for mobile truck Salcomine units producing 1000 cu. ft./hr of high purity oxygen. The difficulties to be overcome in this work were materially and unexpectedly augmented by the realization that mobile units for field service would be required to operate in all climates without dependence on external agents other than the local atmosphere and engine fuel.

This requirement was made only too clear in a discussion between Kellogg representatives and Capt. Beverly (U.S. Army Engineer Corps) on February 6. The mobile unit was thus seen to require not only air and oxygen compressors (driven by gasoline engines) but also heating and cooling devices to move the Salcomine through the necessary temperature range. Atmospheric air became the basic cooling medium while all heat had to be obtained from engine fuel.

To establish designs which would meet the most severe atmospheric conditions that might be encountered in all forseeable combat areas, it was decided to design all ground units for operation in air at 120°F with a dew point of 90°F, a condition which might occur in Pacific Islands lying near the

Equator.

The Salcomine program also visualized the development of units for use on shipboard and in long-range bombing planes. A ground unit capable of being separated into relatively small sections for transportation by plane to remote localities (so-called "air transported" unit) was also contemplated, but at the period in question, February, 1942, greatest emphasis was being placed on mobile truck units for use by the Engineer and Air Corps.

A then-recent development by the M.I.T. group further restricted the design of the equipment. Most reaction vessel designs under discussion involved fixed beds of powdered Salcomine surrounding coils or pipes for the heating and cooling fluids. In view of the poor heat-conducting properties of Salcomine, it would have been highly desirable to employ heat transfer tubes fitted with fins, ribbons or other extended surfaces – thereby greatly shortening the time required to heat or cool the powder through a specified temperature change. Unfortunately the powder, as then prepared, packed into a very rigid cake in the course of operation. It was therefore agreed that it would be almost impossible to remove Salcomine from a reactor fitted with extended surface tubing. Reactor designs were to be drastically restricted to those containing plain tubing arranged for easy cleaning.

At the same time, Kellogg undertook discussions with the Clark Brothers Co. on the specifications for the air and oxygen compressors in the proposed Salcomine units.

During March designs were prepared in some detail for two mobile truck units. These designs differed from one another principally in the shape and internal tube arrangements of the heating surfaces. Both proposed to supply heating and cooling by a continuously circulating refrigerant which was to act as a heating medium at high pressure and a cooling medium at low pressure.

However, when preliminary mobile unit designs were completed it was apparent that Salcomine units would be heavier, larger and more complex than units of the same capacity producing oxygen by the employment of liquid air cycles. Thus, it was estimated that a chemical truck unit producing 1000 cu.ft./hr. would weigh about 8 tons (exclusive of truck or trailer) and would require engines developing about 180 horsepower. Corres-

ponding liquid air units, it was believed, would weigh about
5 tons (exclusive of truck or trailer) and would require
about 80 horsepower.

On March 20, at a meeting with the NDRC oxygen staff,
Kellogg representatives proposed the abandonment of the Salcomine
process for mobile truck units. During this meeting it was point-
ed out that recent laboratory work at M.I.T. indicated that an
adiabatic unit might ultimately be realized. This unit would
operate over a narrow temperature range using very high pressure
air (600 psi or greater) in the absorption step. Such an
arrangement would dispense with the elaborate heating and cool-
ing apparatus required for lower pressure operation.

Accordingly, it was agreed to suspend all further
work on truck units until a laboratory evaluation of the
adiabatic cycle had been made. Meanwhile, studies of units
for generating oxygen on shipboard were to be inaugurated.
These units would depend on ship supplies of steam and cool-
ing water, and would therefore, be much smaller and simpler
than the completely self-contained truck units.

Shipboard Unit (C-2)

On March 26, Kellogg and NDRC representatives con-
fered in Washington with officers of the Bureau of Ships(USN)
to establish the major features of the shipboard unit. It
was agreed at that time to construct a unit similar to those
previously proposed for the truck units, but relying on
supplies of steam and cooling water from external sources. In
addition, the unit would be designed to generate oxygen at 20
psig pressure which was then considered adequate for cutting
torch use and which would obviate the need for an oxygen com-
pressor. It was decided to employ reactors containing flat,
removable coils for the heat transfer fluids with the powder
bed surrounding the coils.

Drawings and specifications for most of the necessary
equipment in the shipboard unit (type C-2) were delivered to
American Machine Defense by the end of March. These were prompt-
ly forwarded to the Whitlock Manufacturing Company at Hartford,
Connecticut, which had undertaken to fabricate the pressure
vessels and erect the unit as sub-contractors to American Machine
Defense.

The general procedure followed by the partici-
pating companies during the ensuing weeks was:

A) Kellogg made process calculations; pre-
pared detailed flowsheets; designed
and prepared assembly drawings for
pressure vessels and other items; pre-
pared detailed specifications; prepared
detailed piping drawings;

B) American Machine Defense, upon receipt
of the foregoing material from Kellogg,
reviewed all designs and suggested
improvements on the basis of their
manufacturing experience; issued pur-
chase orders for all materials and parts;
arranged for shipment and delivery of all
items to their plant or to Whitlock; pre-
pared shop detail drawings; arranged with
American Machine & Foundry Co. for fabri-
cation of all parts requiring close machine
work; shipped to Whitlock all items de-
livered to or fabricated in their plant;

C) Whitlock took delivery and inventoried all
items required in the assembly of the unit;
fabricated the pressure vessels and other
heavy pieces in accordance with instructions
from Kellogg and American Machine Defense;
constructed supporting structures; assembled
piping; erected the entire unit; supplied
utilities from their plant system.

As originally designed in March, 1942, the unit was to
operate on air at 275-300 psi pressure. At about this time the
M.I.T. group undertook a study of the decline in activity ex-
perienced by the Salcomine in use. It was soon noted that, when
operated at these pressures, the chemical lost most of its
activity in much fewer cycles than it did when operated at about
100 psi. By then, construction of the unit was well advanced
and it was decided to leave the design unchanged but to operate
at air of about the latter pressure. Under these circumstances,
with a large air supply available, process calculations indicated
that the unit would produce only 600 cfh instead of the 1000 cfh
which was predicted for the higher pressure operation.

It was also discovered that generation of oxygen under
20 psi pressure (as contemplated in the meeting of March 26)

would be very harmful to the chemical activity of the
Salcomine. Accordingly, during the month of June it was
decided to desorb the oxygen from the reactors at atmospheric
pressure and to employ a 2-stage oxygen compressor to raise
the final oxygen pressure to 150 psi(which was felt to be
necessary for under-water cutting work). A compressor for
this service was ordered at that time from Clark Brothers.

The construction of the unit was greatly delayed
by many shortages of critical materials and components, a
condition which hampered the entire war production program
during most of 1942. As originally designed for shipboard
service, the reactors were to be cooled by circulation of
sea water through the internal coils. These were to be of
cupro-nickel alloy and were to be connected by headers made
from cast Monel metal. It soon developed that those
materials were almost unobtainable under the priority ratings
then assigned to the project. During May the unit was
drastically revised to permit the use of more abundant
materials, with a consequent loss in operating flexibility.
Fresh water was to be used as the coolant; the cupro-nickel
tubes were replaced by brass; and the Monel castings by built-
up assemblies of carbon steel. For marine use, the fresh
water would be cooled in a cupro-nickel, shell-and-tube ex-
changer against a stream of sea water. This scheme merely
shifted the critical alloys from the reactors to the heat
exchanger, but resulted in an overall saving in time required
to develop the unit. It was realized that a considerable
quantity of test work would be required at a shore station
before the unit could be installed on a ship, and it was
clear that the time required for the shore testing (which
would be done with fresh water as the coolant) would be ample
for obtaining the cupro-nickel exchanger.

During June and July it became evident that operations
were moving very slowly at the Hartford plant of the Whitlock
Co. This was not surprising because Whitlock was carrying an
extremely heavy production schedule of equipment for the Navy
and the Rubber program. This condition, combined with the
acute shortage of good mechanic and engineer personnel, made
it impossible for Whitlock to give the experimental oxygen
unit the close attention which it required.

In August, therefore, American Machine Defense
stationed one of its development engineers at the Hartford
plant with instructions to push ahead the fabrication of the
C-2 unit. This arrangement produced a noteworthy improvement,
but to expedite matters further, Kellogg placed a member of

its Operating Department at Whitlock to cooperate with the American Machine Defense representative in hastening the job. It was then learned that certain key components for the unit had been incorrectly or carelessly fabricated and were unusable. To eliminate further cases of this sort, Kellogg inspectors made regular visits to the job during ensuing weeks and passed "official" judgment on current production.

Of the four reactors employed in the complete unit, one was placed in operation on November 12, to be joined by a second reactor the following day. The third reactor went on stream on November 28, and the last reactor was ready by December 14. Exhaustive studies were made to establish the best operating conditions, but in spite of all efforts, the maximum production was only 300-400 cfh. This low production was attributed to several factors:

A) Poor heat transfer characteristics of the plain brass tubing used to heat and cool the Salcomine.

B) Insufficient air supply to the reactors. Because of limitations in the Whitlock compressed air system, the unit usually received 4000-5000 cfh at 80-85 psi instead of the expected 8500 cfh at 90-100 psi.

The unit was given a preliminary demonstration in December before representatives of the Bureau of Ships and the NDRC. At that time plans were made for a more formal showing as soon as all mechanical work was complete. It was also agreed that Kellogg would construct a scale model of a proposed shipboard unit, similar in general to the existing C-2 unit but rearranged and revised to occupy minimum space. This model was intended to demonstrate to Navy officials the layout possibilities which might be attained in future units.

During January the oxygen compressor was received from Clark Brothers. It was installed with an electric motor drive and, after a few preliminary adjustments, was found to give satisfactory service.

In order to improve the heat transfer characteristics of the reactors, it was decided to install finned coils in place of the existing smooth coils. It will be recalled that the smooth coils had originally been selected to facilitate

removal of caked Salcomine from the reactors. During the
Summer of 1942, however, the Rumford Chemical Works had
developed a grade of Salcomine powder which did NOT form
solid cakes in use. Since this non-caking material was
now available for use in the C-2 unit, it became practical
to employ finned coils to improve heat transfer. Such coils
were designed by Kellogg and ordered by American Machine
Defense from the Rome-Turney Company at Rome, N.Y.

On January 20, 1943, the unit was formally demon-
strated to representatives of the Bureau of Ships and the
Office of the Coordinator of Scientific Research and Develop-
ment (USN), in the presence of the NDRC oxygen staff and
personnel of the participating contractors. Bureau of Ships'
representatives expressed great interest in the unit and urged
that the finned coils (then on order) be fabricated and in-
stalled with all possible speed. It was stated that when this
work was complete, the unit should be prepared for shipment to
an overseas base where it would be placed in regular operation
to augment a critical oxygen shortage.

During February, one set of the new finned coils was
received and placed in service. Performance in the reactor was
greatly improved and it was calculated that, when the entire
unit was so equipped, production would easily reach 500 cfh
even with the restricted air supply available. The remaining
finned coils were received and installed during March.

By this time it became clear that the Bureau of Ships
was not going to place the unit in immediate service. All equip-
ment was therefore dismantled and shipped to the Central Engineer-
ing Laboratory of the Oxygen program at the University of
Pennsylvania. It was agreed that the unit would be reassembled
there if Navy interest revived.

The delivery of the unit, on April 16, 1943, to the
Central Engineering Laboratory terminated the work of Kellogg
and American Machine Defense on the development and design of
shipboard oxygen plants.

Shipyard Unit (C-4)

In the early part of 1942 a critical shortage of oxygen
existed in some of the recently established shipyards in various
parts of the country. During March of that year the NDRC re-
quested Kellogg to prepare preliminary designs for a Salcomine
unit to generate oxygen in shipyards, drawing utilities from
local supplies. Kellogg accordingly proposed a slight modifi-

cation of the shipboard unit for this service. Specifications, flowsheets and drawings for this unit were submitted to the War Production Board, the Shore Facilities Section of the Bureau of Ships and the Office of the Coordinator of Scientific Research and Development of the Navy Department.

No further action was taken by Kellogg.

Mobile Truck Units (C-1A and C-1C)

As was previously stated, active design work on these units was temporarily suspended in March, 1942, pending further laboratory studies at M.I.T. During the next two months further experiments made it clear that adiabatic processes would not prove advantageous for the mobile truck units. In May, therefore, process studies were resumed on truck units similar to the types outlined in February and March. Kellogg continued to believe that the Salcomine process was not suitable for truck use in any form, but the project was continued at the request of the Army Air Corps and the NDRC. This decision was motivated by the realization that many aspects of the military oxygen program were not then completely clarified and that, as yet, no possible research lead could safely be neglected.

The prime contract for fabrication and assembly of these units was placed with the Independent Engineering Company at O'Fallon, Ill. A sub-contract for pressure vessel fabrication was arranged with the Whitlock Manufacturing Company. Each unit was to be mounted on two trailers, one containing the Salcomine reactors and the other carrying the engines and compressors. It was further agreed that the compressor-engine trailers for each unit would be fabricated and assembled by Clark Brothers as sub-contractors to Independent Engineering.

Detailed design and purchasing work was begun at once. Due to the usual delays in obtaining critical materials and components, many months elapsed before assembling operations could be started. In the meantime, the development of mechanical units in other parts of the Kellogg organization proceeded very favorably while the original disadvantages noted in the Salcomine units persisted despite prolonged research efforts in many quarters.

At length, the Army Air Corps agreed to the cancellation of these units. On November 24, the NDRC ordered its contractors to terminate their activities and ship any non-returnable or partly fabricated components to the Central

Engineering Laboratory at the University of Pennsylvania.

Kellogg's work in connection with cancellation
and return of materials was concluded in February, 1943.

Bombing Plane Unit

During May, 1942, numerous process and equipment
studies were made in an effort to develop a small Salcomine
unit which would deliver 100 cfh when operated in a bombing
plane at high altitude.

With the information then available, all designs
appeared unattractive because of weight and size require-
ments. The project was accordingly tabled, pending the
development of more active chemical adsorbents for this
very exacting service.

Several months later, work was resumed by the M.
I.T. group and, after numerous studies of reactor designs
and other variables, was permanently dropped.

Medical Corps Unit

During May, 1942, numerous process and equipment
studies were made in an effort to develop a small Salcomine
unit to meet the requirements of the Army Medical Corps.
Due to the difficult heat and pressure requirements placed
upon self-contained units, it was agreed that the Salcomine
process was not attractive for the service contemplated.
The project was dropped.

Air Transported Unit (C-5)

Detailed process studies for this unit were under-
taken in September, 1942. In addition to the usual require-
ments confronting self-contained units, this unit was to be
capable of rapid field assembly from packages not exceeding
20" x 34" x 50". Pieces of equipment and cases smaller than
these dimensions were considered to be suitable for trans-
portation by air to remote localities.

A design was developed, based on a group of packages
of the allowable size, in which each package performed only a
few of the functions demanded of the overall unit. The main
package contained two Salcomine reactors which were to be
heated and cooled by recirculation of gas through the powder

beds. The recirculating gases were heated, or cooled, in exchangers which contacted a circulating refrigerant system not unlike that proposed for the mobile truck units.

Preliminary information on this plan was presented to the NDRC on October 8, 1942. Kellogg took no further action on the project.

Fluid Powder Study

During the preliminary process studies made in February, 1942, Kellogg investigated the possibilities of applying the fluid powder technique to the Salcomine process. This new method for handling gases and solids was then finding very wide application in the expanding aviation gasoline program, and it seemed reasonable to consider its utility in the task at hand for the NDRC.

Preliminary designs did not seem attractive because of the very large pressure changes to which the fluidized gas-powder mixture would be subjected. It was felt that no further process studies should be made until some laboratory work was done to determine whether or not the oxygen-making process would actually occur under fluid powder conditions.

In July of the same year, Kellogg submitted to the NDRC an estimate covering the cost of erecting and operating a Salcomine fluid powder pilot plant at the Kellogg Laboratories in Jersey City, N.J.

The proposal was not authorized and Kellogg did no further work on the matter.

Miscellaneous Process Studies

Kellogg prepared engineering appraisals of several process and equipment schemes developed by other participants in the NDRC program. Among these were:

A) Salcomine-Oil Suspension

Preliminary studies were made by the DuPont Company of a plant circulating suspension of Salcomine in white oil. A flowsheet for a truck unit prepared by DuPont was appraised by Kellogg. It was con-

cluded that such a unit would
not compare favorably with
liquid air units of the same
capacity.

B) Screw-Conveyor Unit

Brief engineering studies were
made by Kellogg of a unit develop-
ed at the University of Iowa.
This unit employed Methomine (a
then-new Salcomine derivative)
which was moved through the
process cycle by a system of
screw conveyors. The unit was
not recommended for further con-
sideration.

C) Tessie duMotay Process

Kellogg inspected the pilot plant
erected by DuPont for their modifi-
cation of this process. After a
review of energy and equipment re-
quirements it was concluded that
the process might be applicable
for shipyard units. It was not
considered suitable for truck or
shipboard service. Kellogg sub-
mitted a report on these findings
to the NDRC on December 16,1942.
No further action was taken.

Miscellaneous Shop Work

In addition to activities previously described, the
American Machine Defense Corporation ordered and supervised
the execution of several miscellaneous fabrication jobs in
the shops of the parent company, the American Machine &
Foundry Company.

Among these were:

A) Fabrication of several Collins-type heat exchangers
for the mobile mechanical units and
for research studies at Yale University.

B) Automatic timers (according to Kellogg
designs) for use on the Salcomine
and mechanical truck units.

BIBLIOGRAPHY

Detailed information concerning the work summarized in this report will be found in the following tabulation of correspondence and reports (arranged by type of unit or project):

Shipboard Unit (C-2)

A) M. W. Kellogg Company equipment specifications dated April 25, 1942(revised June 1, 1942)

B) M. W. Kellogg Company progress reports to NDRC (July 15, 1942 through April 15, 1943).

C) M. W. Kellogg Company Report "Small Oxygen Plants (Salcomine Process) for Shipboard Installation", January 19, 1943.

Shipyard Unit (C-4)

M. W. Kellogg Company equipment specifications dated April 20, 1942(revised May 14, 1942).

Mobile Truck Units (C-14 and C-10)

M. W. Kellogg Company progress reports to NDRC (June 15 through December 15,1942)

Bombing Plane Unit

M. W. Kellogg Company letter from Walter E. Lobo to C. C. Furnas at NDRC Washington Office, May 25, 1942.

Air Transported Unit (C-5)

M. W. Kellogg Company letter from Walter E. Lobo to C. C. Furnas at A. D. Little Co. New York City Office, October 8, 1942.

BIBLIOGRAPHY CONTD.

Fluid Powder Study

M. W. Kellogg Company letter from Walter E.
Lobo to C. C. Furnas at NDRC Washington
Office, August 6, 1942.

Tessie duMotay Process Study

M. W. Kellogg Company letter from Walter E.
Lobo to E. P. Stevenson at A. D. Little
Co., Cambridge, Mass. Office, December
19, 1942.

PROCESS CALCULATIONS

Basis of Design (As of March 10, 1942)

Output – 1000 CFH Oxygen at STP (60°F, 1 atm)

Number of Reactors – 4

Cycle Time on Each Reactor:

Absorption	3' 0"
Evacuation	20"
Heating and Desorption	5'40"
Valving	5"
Cooling	2'50"
Valving	5"
	12'00"

Absorption Pressure	250 lbs gage
Desorption Pressure	Atmospheric
Absorption Temperature	35°C – 95°F
Desorption Temperature	100°C – 212°F

% Oxygen in Compound After Absorption	3.65%	based on weight of compound
% Oxygen in Compound Before Absorption	0.30%	
Yield	3.35%	(From data in letter of December 4,1941 from E.R. Gilliland to C.C. Furnas)

% Oxygen Desorbed   93% of Oxygen Absorbed

True Density of Salcomine   1.5
Packed Density of Salcomine 0.7

Exit Gas Rate   4 CFH per 40.7 GRS of Salcomine at 25°C and 1 atm

Compound Required

Weight of Oxygen Produced $= \dfrac{1000 \times 32}{379} =$ 2.64 mols/hr x 32=84.5 lbs/hr

Assuming 3% Loss in Voids,etc. O_2 Desorbed $= \dfrac{84.5}{1.03}$ = 87.0 lbs

Compound Required   Contd.

Frequency -- 5 complete cycles/hr

Weight of compound $= \dfrac{87.0}{5} \times \dfrac{100}{3.35}$ = 519 lbs of unsaturated compound

= 519 x 1.045 = 542 lbs of saturated compound

Compound per reactor $= \dfrac{542}{4} = \underline{135}$ lbs

Air Required (for absorption at 250 lbs/sq.in. and original cycle)

Exit gas rate = 4 CFH per 40.7 GRS of sat. Salcomine at 25°C

Total exit gas $= \dfrac{135 \times 454}{40.7} \times 4 \times \dfrac{520}{537}$ = 5820 CFH

Air input = 5820 + 1000 CFH O_2 = 6820 CFH @ 60°F, 1 atm

O_2 yield $= \dfrac{1000}{6820 \times .21}$ 100 = $\underline{70\%}$

Reactor Design

28 flat spiral coils of 9/16" OD copper tubing, turns 7/8"
between centers with the horizontal coils 0.76" apart.

Fraction Void in Salcomine

packed density   0.7
true density   1.5

Fraction void $= 1 - \dfrac{\text{packed density}}{\text{true density}} = 1 - \dfrac{0.7}{1.5}$ = 0.53

Estimated Weight of Reactor

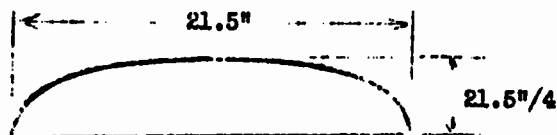|	
Coils and coil fittings	185 lbs
Flanges and bolts	160 lbs
Top head	60 lbs
Bottom head	50 lbs
Bottom header	75 lbs
Top header	30 lbs
Shell, core, screens	145 lbs
	705 lbs

Effective Compound in Reactor

Reactor Volume

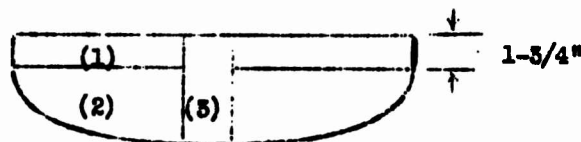**Shell**   24.75" ID x 21.375 h
3.00" OD   core

$$(24.75^2 - 3^2) \frac{\pi}{4} \times 21.375 = 10,140 \text{ cubic inches}$$

Lower Head

Vol. 1 head = $\frac{1}{2}$ $\frac{4}{3}$ $\pi a^2 b$ where b = $\frac{21.5}{4}$ and a = $\frac{21.5}{2}$

$$V = \frac{2\pi}{3} \left(\frac{21.5}{16}\right)^3 = \frac{\pi}{24} (9938) = 1300 \text{ cubic inches}$$

Vol. of cylindrical part (1) = $\frac{\pi}{4}$ $(24.75)^2$ x 1.75 = 842 cu.inches

Vol. of part (3)   = $\frac{\pi}{4}$ 9 x 7.25 = 51.2 cu. inches

Total vol. = (1) + (2) - (3) = 1300
                                   + 842
                                   ─────
                                    2242

                                    - 51
                                   ─────
                                    2191 - say 2190 cubic
                                          inches void

Upper Head

(1) Vol. of ellipsoidal part $= \frac{2}{3} \pi \frac{(24.5)^3}{16} = \frac{\pi}{24} (14706) = 1925$ cu.in.

Neglect effect of glass wool

(2) Cylindrical part -
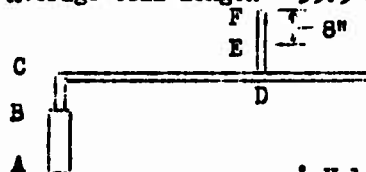
$$V = \frac{\pi}{4} (24.5^2 - 49) \frac{7}{8} = 378 \text{ cubic inches}$$

(3) $V = \frac{49 \pi}{4} \times 2 = 77$ cubic inches

(4) Vol. of tubes $= 4.75 \times \left(\frac{9}{16}\right)^2 \frac{\pi}{4} \times 28 = 33$

$$
\begin{array}{ll}
\text{Total vol.= (1) + (2) -(3) -(4) =} & \begin{array}{r} 1925 \\ 378 \\ \hline 2303 \end{array} \quad \begin{array}{r} 77 \\ 33 \\ \hline 110 \end{array} \\
& \begin{array}{r} 110 \\ \hline 2193 \end{array} \quad \text{say 2200 cubic inches}
\end{array}
$$

Volume of Pancake Coils

Average coil length = 35.5 feet overall = A to F

C-B = 1-3/8
A-B = 11-5/8 - 1-3/8 = 10-1/4

$\therefore$ BCDE = 35.5' - 18-1/4"
= 35.5' - 1.5' = 34 feet

$\therefore$ Vol. of BCDE = 34 x 12 x $\left(\frac{9}{16}\right)^2 \frac{\pi}{4}$ x 28 = 2840

Vol. of BA = 10.25 x 28 x $\left(\frac{7}{8}\right)^2 \frac{\pi}{4}$ = 172 cubic inches

Volume of Pancake Coils   Contd.

Total tube vol. = 2840 + 172 = 3010 cubic inches

Spacer volume = $\frac{3}{8} \times \frac{3}{8} \times 6 \frac{7}{8} \times \frac{3}{4} \times 84$ = 60 cubic inches

Tubes and spacers = 3070 cubic inches

Net compound volume = 10140 - 3070 = 7070 cubic inches = 4.09 cu.ft.

Weight of compound = 4.09 x 62.5 x .7 = <u>179 lbs/reactor</u>

Active Portion of Compound

Edge: Assume Salcomine within 1/2" of tubes will desorb

∴ A layer of compound 3/4" deep will be inert all around
the walls.

Volume of this annulus = approx. 24 π x 21.375 = 1610 cubic in.
less vol. of BA   <u>170</u>
1440 cubic in.
inert

Center: Radius of inert core = 3"

Volume of annulus = $(6^2 - 3^2) \frac{\pi}{4} \times 21.375$ = 453 cubic inches

Volume of ED   = $28 \times \left(\frac{6}{16}\right)^2 \frac{\pi}{4} \times 10"$ = 70 cubic inches

Net volume = 453 - 70 = 383 cubic inches inert

Total = 1440
<u>383</u>
1823   = 1.1 cubic feet

1.1 x .7 x 62.5 = 48.3 lbs.inert compound
say 49 lbs.

Effective compound = 179
<u>-49</u>
130 lbs.

Expected Reactor Performance

Reactor as designed contains 179 lbs. of saturated Salcomine of which 130 lbs. are effective.

Maximum Expected Production (for max. consumption of utilities)

Abs. temp. - 68°F at 105 lbs/sq.in.abs.
Desorb temp.- 212° F at atm.

Cycle		
	Abs.	- 6 min.
	Des.	- 4 min.
	Cool	- 2 min.
	Vac.	- 1/2 min.
		12-1/2 min.

$$\text{frequency} = \frac{60}{125} = 4.8$$

Exit gas rate - 4 CFH/40.7 grams Salcomine @ 25°C and 1 atm.

Absorption = 3.47% from completely desorbed Salcomine
Desorption = 93%
Residual O_2 = 3.46 x .07 = 0.2
Net yield = 3.45%

O_2 production = 130 x 0.0345 x 4 x 4.8 = 86.1 lbs/hr

less void loss which = 4.2 x 0.065 x 4 x 4.8 = 8.1 lbs/hr

Net production = $(86.1 - 8.1) \times \frac{1000}{84.5}$ = 925 CFH

Air consumption = $2 \left(\frac{179 \times 454}{40.7} \times 4 \times \frac{520}{537} \right)$ + 925 = 16385 CFH

O_2 yield = $\frac{925}{16385 \times .21}$ 100 = 27%

Cycle As Designed (12' total, 3 min. abs.)

Exit gas rate - 4 CFH/40.7 gr. Salcomine at 25°C

Absorption = 2.25%
Net yield = 2.23%

O_2 production = 130 x 0.0223 x 20 = 58.0 lbs/hr

Void loss = 4.2 x .065 x 20 = 5.5 lbs/hr

Cycle As Designed   Contd.

Net production = $52.5 \times \dfrac{1000}{84.5}$ = 622 CFH

Air consumption = $\dfrac{179 \times 454}{40.7} \times 4 \times \dfrac{520}{537}$ + 622 = 8352 CFH

Oxygen yield = $\dfrac{622}{8352 \times .21} \times 100$ = 35%

Purity of Product

Volume of reactor shells = 2300 cubic inches – upper head
+ 2190 " " – lower head
4490 " " total = 2.6 cubic feet

Most recent data at time of writing, October 5, 1942, indicates
that Salcomine is 39% voids and weighs 42 lbs/cu.ft.

Volume of compound per reactor = 4.09 cubic feet
ρ_G = density of O_2 left in powder
Volume of gas in Salcomine voids = 4.09 x .39 = 1.6 cubic feet
Total volume of residual gas =
vol. in voids + vol. in heads = 1.6 + 2.6 = 4.2 cubic ft.

Assume this gas is air because reaction rate is nearly zero at
end of absorption.

∴Nitrogen in residual gas = (4.2) (.79) (ρ_G) lbs. = $3.3\,\rho_G$
where ρ_G = air density in voids
Oxygen evolved = $\dfrac{84.5}{20}$ lbs/hr = 4.22 lbs/reactor per cycle

Approx. % N_2 in O_2 = $\dfrac{3.3\,\rho_G}{4.2}$ 100 = $\dfrac{330\,\rho_G}{4.2}$ = $79\,\rho_G$

ρ_G at 80° and 760 mmHg = 0.076 lbs/cu.ft.

ρ_G at 80° and any pressure (Pmm) = 0.076 x $\dfrac{P}{760}$ =

For pressure after evacuation of Pmm, average % N_2 in O_2 is

$$\% \ N_2 = (79) \ \dfrac{(0.076)}{760}(P) = 0.0079 \ P$$

O_2 purity = 100 - 0.0079 P

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Oxygen Losses in Voids

Total voids = 4.2 cubic feet

Density of O_2 at 100°C and 1 atm. = 0.065 lbs/cu. ft.

Loss per hour = 4.2 x 0.065 x 20 = 5.46 lbs/hr

O_2 product = 84.5 lbs/hr

% loss = $\dfrac{5.46}{84.5 + 5.46}$ 100 = 6.1%

Oxygen Coolers

Oxygen Cooler (between reactors and compressor) "C-1"

Duty - cooling 84.5 lbs/hr of O_2 from 210°F to 100°F

h of O_2 at 210° and 1 atm. = 143.2 BTU/lb (G-605.30)*
h of O_2 at 100° and 1 atm. = 119.2 " "
$\triangle$ h = 24.0 " "

Total duty = (24.0) (84.5) = 2030 BTU/lb

Cooling medium - 85° water
Pressure drop in O_2 <0.5 lbs/sq.in.

Oxygen Compressor Coolers   "C-2" and "C-3"

Suction to 1st stage   - 100°F and 1 atm.
Discharge from 1st stage - 306°F and 49.0 lbs/sq.in.abs.
Suction to 2nd stage   - 100°F and 49.0 lbs/sq.in.abs.
Discharge from 2nd stage - 306°F and 165.0 lbs/sq.in.abs.
Suction to holder   - 100°F and 165.0 lbs/sq.in.abs.

Compressor discharge temperatures based on n = 1.35 instead of 1.40 to correct for non-adiabatic compression.

Cooling medium - 85° water C_p for O_2 = 0.22 BTU/ lb.°F

Duty to C-2 cooler = (84.5) (306 - 100) (0.22) = 3850 BTU/hr
Duty to C-3 cooler = (84.5) (306 - 100) (0.22) = 3850 BTU/hr
Pressure drop in O_2 streams < 2.0 lbs/sq.in.

* Note: Number in parenthesis refers to chart in M. W. Kellogg Company Technical Data Book.

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Oxygen Compressor Coolers "C-2 and "C-3" Contd.

Total cooler duties -

C-1	2050	
C-2	3850	
C-3	3850	
	9750	BTU/hr

Oxygen Holder

Desorption data from E.R. Gilliland on May 13, 1942
- 90° C from 35° C   5.37% absorbed

Time (θ)	% Desorbed (P)	ΔP	Δθ	ΔP/Δθ	$\frac{dP}{d\theta}$	$\frac{dP}{d\theta}$
0	0				0	16.7
		4.0	1/2	8.0		
1/2	4.0				14.8	30.5
		9.5	1/2	19.0		
1	15.5				21.9	36.9
		12.5	1/2	25.0		
1-1/2	26.0				25.2	39.4
		13.4	1/2	26.8		
2	39.4				22.4	34.8
		8.7	1/2	17.4		
2-1/2	48.1				18.3	27.4
		8.6	1/2	17.2		
3	56.7				18.7	21.7
		8.8	1/2	17.6		
3-1/2	65.5				15.7	
		8.6	1/2	15.2		
4	72.1				15.0	
		10.7	1/2	21.4		
4-1/2	82.8				14.2	
		4.7	1/2	9.4		
5	87.5				12.4	
		8.7	1	8.7		
8	96.2				5.0	

Calculation of rate of oxygen evolution as a function of desorption time. dP/dθ by graphical differentiation.
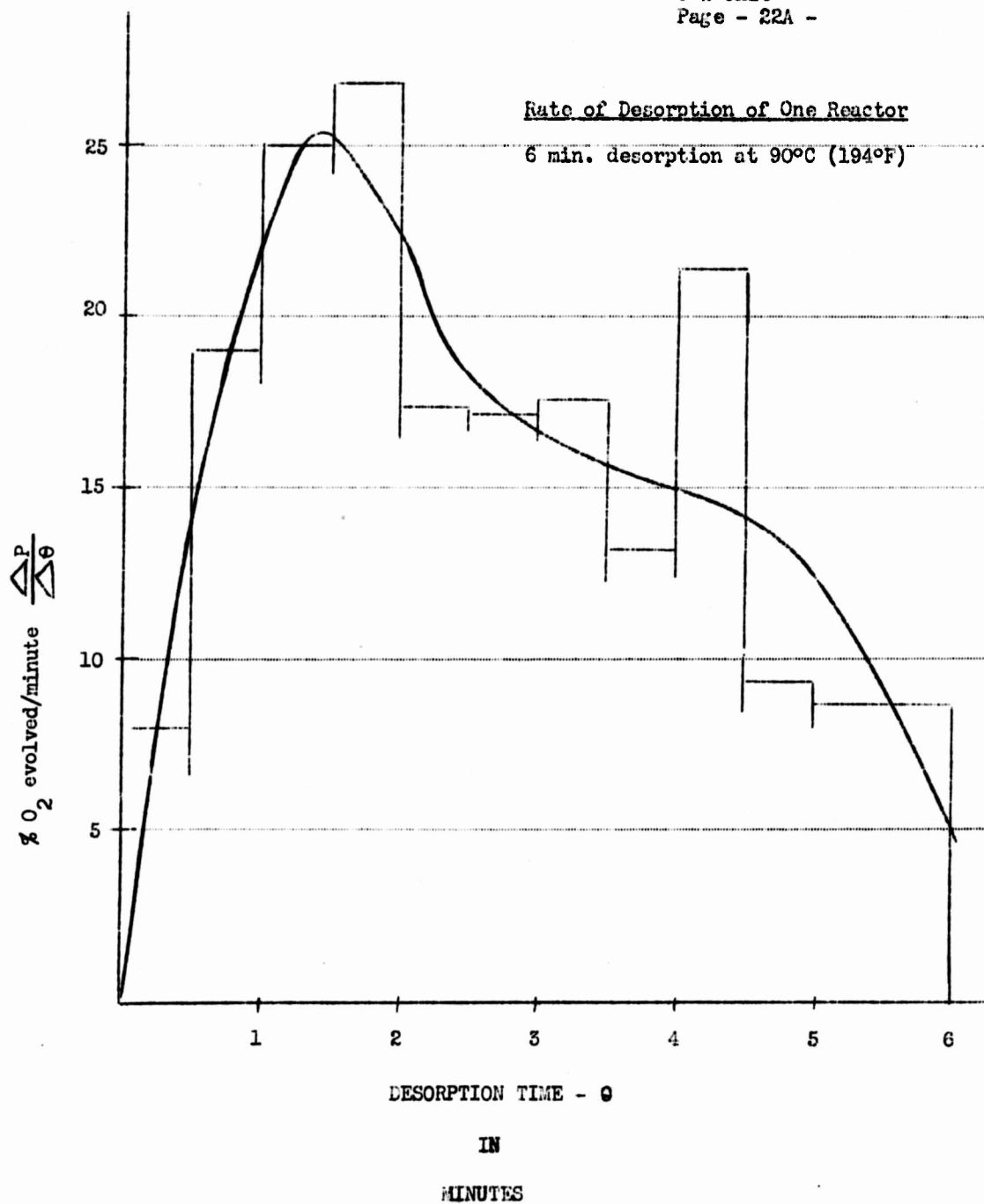
Col. 6 is table of values of dP/dθ for one reactor alone.
Col. 7 is table of values of dP/dθ for two reactors desorbing with three minutes overlap.

Rate of Desorption of One Reactor

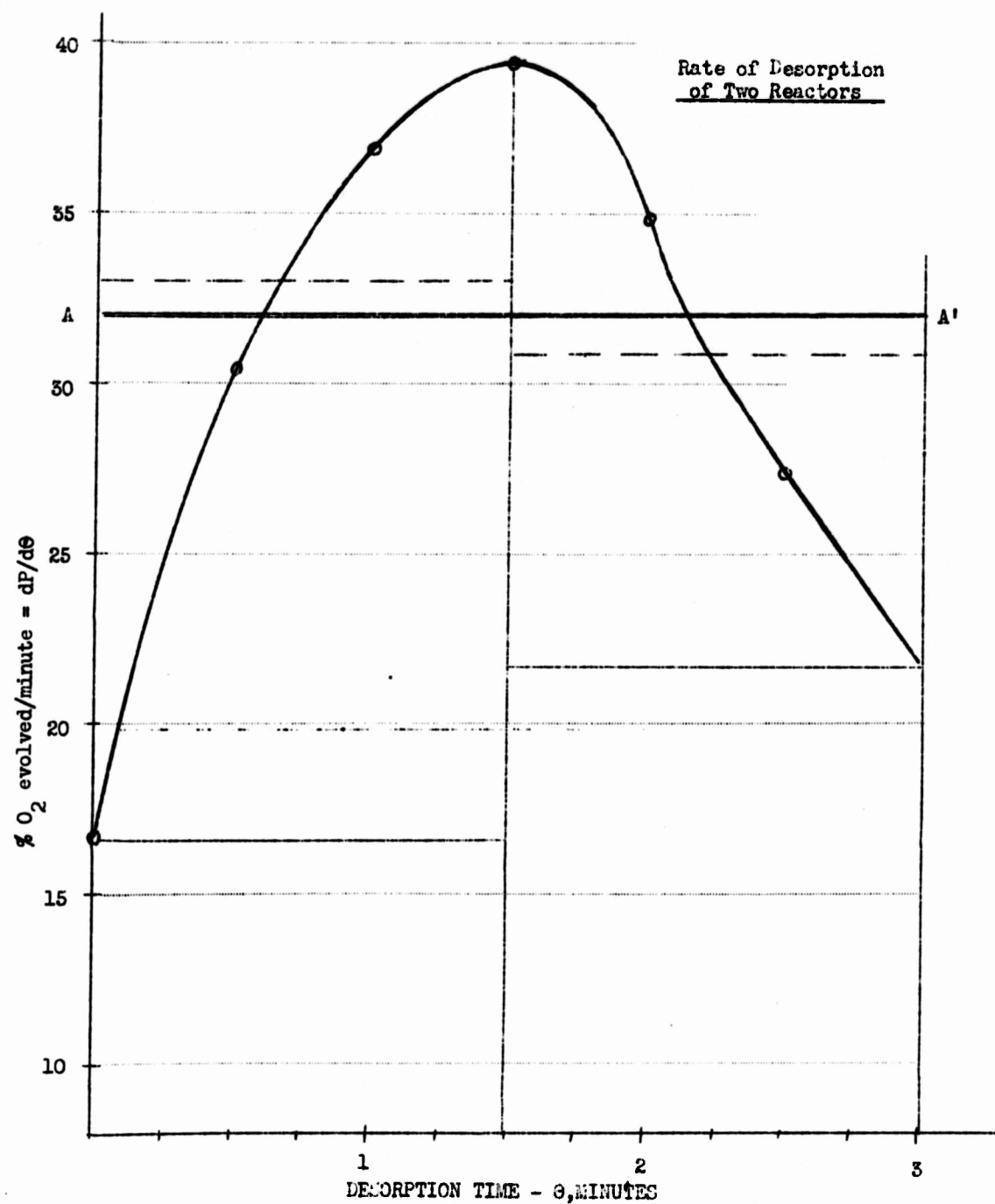6 min. desorption at 90°C (194°F)

DESORPTION TIME - θ

IN

MINUTES

Rate of Desorption
of Two Reactors

DESORPTION TIME - θ, MINUTES

% O$_2$ evolved/minute = dP/dθ

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Curve on page 22B is plot of rate of O_2 evolution (expressed as a percent)against time for two reactors desorbing on a three minute overlap.   Data from Col.7 page 22 .

Average rate is about 32% in one minute as shown by line AA'.

Area above AA' is equal to 9% of area below AA', i.e.,peak load to be carried by O_2 holder is 9% of total flow in three minutes.

Total flow in three minutes = $\frac{1000}{60}$ x 3 = 50 cubic feet

9% of 50 cubic feet = 4.5 cubic feet - theoretical holder volume.

Use a holder 18" in diameter and 5' long with internal volume of 8.5 cubic feet to allow 90% safety factor.

Heat Duty

Heat Duty to Reactors (for original cycle with 68° water)

Item	Heated Through Entire Temp.Range	Heated Through 65% of Temp.Range
Coils and fittings	185	
Flanges and bolts		160
Top head		60
Bottom head		50
Bottom header	75	
Top header	30	
Shell, core, screens		145
	290	415
	270	x .65
	560 lbs.total through entire temp. range	270 through entire range

Heat Duty

Heat of reaction 2.64 x 19,000 x 1.8 = 90,400

Sensible heat to Salcomine
(179)(212 - 68)(0.25)(20) = 129,000

Sensible heat to metal
(560)(212 - 68)(0.10)(20) = 161,000
380,400 BTU/hr

Duty to O_2 coolers   9,750
Total duty   390,150 BTU/hr

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Cooling Water System

Ave. temp. change in water ~ 10° F

Water rate = $\dfrac{390,150}{10 \times 60}$ = 650 lbs/min. = 78 GPM

Fresh water cooler "C-4"

Duty - 400,000

Fresh water rate - 80 GPM

Fresh water temp. change - 10°

Temp. approach - 10° between sea water in and fresh water out

Sea water rate - 160 GPM

Sea water temp. change - 5°

Fresh water pump "J - 4" to deliver 80 GPM at room temp. and
80 lb/sq.in. ga. discharge pressure

Steam System

Heat duty to steam = reactor duty only = 380,400 BTU/hr

Assuming latent heat of steam at 1000 BTU/lb,
steam consumption =

$$\frac{380,400}{1000} = 380 \text{ lbs/hr}$$

say 400

Analysis of Dryer Heat Loads

Dryer Weight

Assume shell is 3/16" thick x 7-3/4" ID x 38" tall

Shell weight = $\dfrac{3}{16} \times \left(7\dfrac{3}{4} + \dfrac{3}{16}\right)$ x 38 x 0.28 lbs/cu.ft. x π = 50 lbs.

__Dryer Weight__   Contd.

Weight of head $=(11\ 3/8)^2\ \frac{\pi}{4} \times \frac{5}{8} \times 0.28 \quad \cdot\ = 18$ lbs.

Wt. of bottom $=(8\ 1/8)^2\ \frac{\pi}{4} \times \frac{5}{8} \times 0.28 \quad = \quad 9$ lbs.

Wt. of flange $=(11\ 3/8^2 - 8\ 1/8^2)\frac{\pi}{4} \times \frac{5}{8} \times 0.28 = \quad 9$ lbs.

Bolts $\quad\cdot$ $\qquad\qquad\qquad\qquad\qquad$ 10 lbs.

Screens $\qquad\qquad\qquad\qquad\qquad\qquad\underline{\quad 4}$ lbs.
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad$ 100 lbs.

Alumina volume without inner insulation:

$\left(7\ \frac{5}{4}\right)^2 \frac{\pi}{4} \times 32" = 1510$ cubic inches $= 0.875$ cubic feet

Wt. of alumina $= 0.875 \times 50 = 43.8 \approx$ __44 lbs.__

__Heat Duty__   No insulation

Final alumina temp. = 500°F   after heating
Initial alumina temp. = 100°F   after cooling
Atmosphere temp.   = 80°F

Thermal conductivity of steel $= k = 26\ \dfrac{BTU}{(hr)(sq.ft.)(°F)/ft.}$

$R_{steel} = \dfrac{L}{kA} = \dfrac{\frac{5}{8} \times \frac{1}{12}}{26 \times 1} = 0.0012\ \dfrac{(hr)(°F)}{(BTU)(sq.ft.)}$

For air film $(h_r + h_c) = 4\ \dfrac{BTU}{hr.°F\ sq.ft.}$ Perry, 2nd ed. page 987
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ table 14

$R_{film} = \dfrac{1}{hA} = \dfrac{1}{4 \times 1} = 0.25\ \dfrac{hr\ °F}{(BTU)(sq.ft.)}$

Total resistance $= 0.25 + 0.0012 = 0.2512$

Total $\triangle T = 500°F - 80°F = 420°F$

$\triangle T$ through steel $= 420 \times \dfrac{0.0012}{0.2512} = 2°F$

$\therefore$ average final steel temp. $= 500°F - \dfrac{2}{1} = 499°F$. say 500°F

Water Absorption (1 hr. cycle, 30 minutes drying)

Air dew point = 80°F
Vapor pressure of water @ 80°F = 0.5067 lbs/sq.in.
Partial pressure of dry air at 1 atm. = 14.7-0.5067 = 14.2 lbs/sq.in.
Partial pressure of dry air at 105 psia = 105-0.5067 = 104.5 lbs./sq.in.

Water content of saturated air at 1 atm. = 0.02226 lbs water/lb. dry air (from tables)

Water content of air at 105 psia =

$$0.02226 \times \frac{14.2}{104.5} = 0.00302 \text{ lbs water/lb dry air}$$

Design air flow rate = 875 lbs/hr.
Design water input = 875 x 0.00302 = 2.64 lbs water/hr.

Water absorbed per cycle = 1.32 lbs.

$$\frac{1.32 \times 100}{44} = 3\% \text{ saturation on alumina}$$

Heat Leak

Initial $(h_c + h_r) = 2$

Final $(h_c + h_r) = 4$ Average = 3 BTU/hr.sq.ft.°F

Dryer Surface Area =

End	8 1/8" dia.	= 0.3600 sq.ft.
Top	11 3/8" dia.	= 0.7050 " "
Top edge	1 1/4" x 11 3/8" x π x 1/144	= 0.3100 " "
Top flange	0.7050 - 0.3600	= 0.3450 " "
Side	8 1/8 x π x 38 x 1/144	= 6.55 " "
		8.2700 sq.ft.

say 8.3 sq.ft.

Initial temp. difference = 20°
Final temp. difference = 420°

Mean $\triangle$T   = 220°F

Heat leak = $(h_c + h_r)$ A$\triangle$T = (3)(8.3)(220) = 5500 BTU/hr

Heat Leak Contd.

Add 25% for safety $\Longrightarrow$ heat leak = 7000 BTU/hr
and for 15 min. = 1700 BTU

Total Heat Duty (one cycle)

To H_2O	$= 1.32 \times 1000$	1320 BTU
To alumina	$= (44)(500-80)(0.20)$	3700
To metal	$= (100)(500-80)(0.12)$	5020
To heat leak	=	1700
		11740 BTU in 15 min.

Power rate $= \dfrac{11740 \times 4}{3420} = 14$ KW

Insulated Dryer

Use lead slag wool inside shell so that alumina bed dia. = 6"

New alumina volume $= 6^2 \dfrac{\pi}{4} \times 32" = 906$ cu.in. = 0.525 cu.ft.

Weight of alumina = 0.525 × 50 = 26 lbs.

Water Absorption

In 30 minutes = 1.32 lbs.

% saturation $= \dfrac{1.32 \times 100}{26} = 5.1\%$ OK

Wt. of insulation(12 lbs/cu.ft.)$= \left[\left(7\frac{3}{4}\right)^2 - (6)^2\right]\dfrac{\pi}{4} \times \dfrac{32}{1728} \times 12 = 4.2$ lbs.

Heat capacity $= 0.22 \dfrac{BTU}{(lb.)(^\circ F)}$

Temperature Differences

k for lead slag wool $= 0.022 \dfrac{BTU}{hr.sq.ft.^\circ F/ft.}$ ✓ 05°F

Use 0.026 to correct for effect of higher temperature.

Depth of insulation = 7/8" = 0.073 ft. = L

Temperature Differences   Contd.

Inside insulation area $= \dfrac{6\,\pi \times 52}{144} = 4.18$ sq.ft.

Outside insulation area $= \dfrac{7\text{-}5/4\ \pi \times 52}{144} = 5.40$ sq.ft.

Log mean area = 4.8 sq.ft.   (E-1.501)

R_i = resistance of insulation $= \dfrac{L}{kA} = \dfrac{0.073}{0.026 \times 4.8} = 0.585\ \dfrac{\text{hr.}^{\circ}\text{F}}{\text{BTU}}$

R_t (through shell) $= R_{film} + R_m + R_i = 0.25 + 0.0012 + 0.585 = 0.8362$

(Note: Neglecting effect of changes in area on metal and film
resistances)

Total $\triangle T = 500\text{-}80 = 420^{\circ}$

$\triangle T_m = 420 \times \dfrac{0.0012}{0.8362} = 0.60^{\circ}F$ Mean T_m = 206°,

$\triangle T_{film} = 420 \times \dfrac{0.25}{0.8362} = 125.6^{\circ}F$ Mean T_f = 105°

$\triangle T_i = 420 \times \dfrac{0.585}{0.8362} = \dfrac{293.8^{\circ}F}{420.0^{\circ}F}$ Mean T_i = 353°
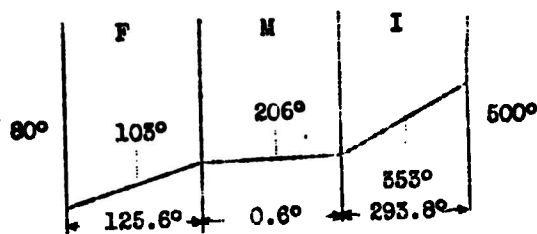
Heat Leak from Shell

Initial film $\triangle T$ = (say) 5°
Final film $\triangle T$ = 125.6°

Heat Leak From Shell Contd.

$$\text{Mean } \triangle T = \frac{125.6 + 5}{2} = 66^{\circ}$$

$(h_c + h_r) = 2$ ($\triangle T$ calculated from $(h_c + h_r) = 4$)

Revised $\triangle T$'s

Assume $(h_c + h_r) = 2.4$

$$\therefore R_f = \frac{1}{2.4 \times 1} = 0.417$$

$$R_t = 0.417 + 0.0012 + 0.585 = 1.0032$$

Final Temp.

$$\triangle T_f = 420 \times \frac{0.417}{1.0032} = 174.5^{\circ} \qquad \text{Mean } T_f = 167^{\circ}$$

$$\triangle T_m = 420 \times \frac{0.0012}{1.0032} = 0.50^{\circ} \qquad \text{Mean } T_m = 254.5^{\circ}$$

$$\triangle T_1 = 420 \times \frac{0.585}{1.0032} = 245.2^{\circ} \qquad \text{Mean } T_1 = 377^{\circ}$$

Revised Heat Leak

$$\text{Mean} \triangle T = \frac{174 + 5}{2} = 90^{\circ}$$

Mean $(h_c + h_r) = $ say 2
$\qquad$ (= 5.68 sq.ft.)

Heat leak = $(2) \left(8 \tfrac{1}{8} \pi \times \frac{52}{144} \right)(90) = 1020$ BTU/hr through shell

<u>Revised Heat Leak</u> Contd.

Assume that rate of heat leak through remainder is at same rate as in uninsulated case.

Remaining area = 8.27-5.68 = 2.59 sq.ft.

Heat leak = (3)(2.59)(220) = 1710 BTU/hr

$$+ \quad \frac{1020}{2730} \text{ " "}$$

Total

for 15 min. leak = $\frac{2730}{4}$ = 680 BTU

Heat Duty

To H_2O = 1.32 x 1000	1320
To alumina = (26)(500-80)(.20)	2180
To metal =	
shell - (50)(254.5-80)(0.12)	1050
heads,etc.(50)(500-80)(0.12)	2520
To insulation (4.2)(352-80)(0.22)	252
To heat leak	680
	8002 BTU in 15 min.

Power rate = $\frac{8002 \times 4}{3420}$ = 9.36 KW

Safety factor = $\frac{10-9.36}{10}$ 100 = 6.4%

Utilities & Supplies

Steam

Low pressure - 400 lbs/hr
High pressure (150 lb)-   20 lbs/hr @ rate of 100 lbs/hr

Sea Water

160 gals/min @ 80 lb/sq.in. ga. pressure

Air

At 90 lbs/sq.in.gage - 16400 CFH max.

Electricity

230 v 60 cycle AC, 10 KW

Fresh Water

150 gals. in system

Salcomine

720 lbs.

Alumina

80 lbs.

INDEX OF DRAWINGS

Shipboard Unit

M. W. Kellogg Company Drawings

Drawing #	Date	Title
2-A	3/25/42	Flat Spiral Coil Type Reactor
11-A	3/31/42	Flat Spiral Coil Type Reactor
13-A	3/26/42	Layout of Piping
14-A	4/20/42	Flat Spiral Coil Type Reactor
25-A	5/26/42	Flow Diagram
12-B	4/9/42	Dryers, Filter and Drip Drum
18-B	4/13/42	O_2 Cooler
20-B	4/24/42	Electric Heater
22-B	5/6/42	Support Frame for Two Reactors and Piping
23-B	5/23/42	Modified All Steel Construction of Reactor
1-D	5/2/42	Typical Piping Arrangement for Flow Recorders
8-D	9/12/42	Revision to Construction of Reactor
2-G	4/13/42	1' x 5' (30 gal.) Tank
3-G	4/22/42	Adapter for Reactor Coils and Wrenches
4-G	4/30/42	Support Frame for Oil Filter, Dryers and Drip Drum
5-G	5/11/42	Single Tube Keyes-Collins Heat Exchanger
6-G	6/8/42	Instrument Panel
7-G	6/11/42	Electric Wiring Diagram
14-G	8/5/42	Modification of Screens in Reactor
28-G	9/19/42	"Hopcalite" Gas Filter
97-G	3/25/43	Two Stage Oxygen Compressor Piping

American Machine & Foundry Company Drawings

Drawing #	Date	Title
MWK-1	6/22/42	Interval Timer Bed Plate
MWK-A005	6/22/42	Interval Timer
MWK-A006	9/30/42	MWK Pneumatic Interval Timer-Compound Gearing
Part MWK-3A1-10	10/1/42	Interval Timer Drum (36 functions)
Part MWK-3A1-11	10/1/42	Interval Timer Drum (10 functions)
Part MWK-3D1-Blank	10/1/42	Interval Timer Segment

INDEX OF DRAWINGS CONTD.

Shipboard Unit

Whitlock Manufacturing Company Drawings

Drawing #	Date	Title
L-9994-A-1	5/25/42	30" OD Fabricated Steel Top Head
L-9994-B-1	5/25/42	Fabricated Steel Bottom Header
B-9994	5/26/42	Flat Spiral Coil Type Reactor
*A-1	2/4/43	"Lobo Job" Reactor Alteration
*1	2/4/43	Top Head Flange (Lobo Job)
*2	2/4/43	Top Head Stuffing Box Body (Lobo Job)
*3	2/4/43	Bottom Head Stuffing Box Body (Lobo Job)
*4	2/4/43	Stuffing Box Gland (Lobo Job)
*5	2/4/43	Stuffing Box Parts List

*Note: These drawings bear the Whitlock Title Box corrected to read "AMD Co.". They were prepared at the Whitlock plant by an engineer from the American Machine Defense Corporation.

Clark Brothers Company Drawings

|		
103-48	8/1/42	2 State Vertical Compressor
103-50	8/17/42	Motor Driven 2 Stage Comp. Unit

Schematic Flow Sheets and Sketches

Following pages contain schematic flow sheets of the basic stages in the operation of the Shipboard unit. There is also appended a sketch of the automatic timer which actuates the valves controlling the various gas and liquid streams in the unit.
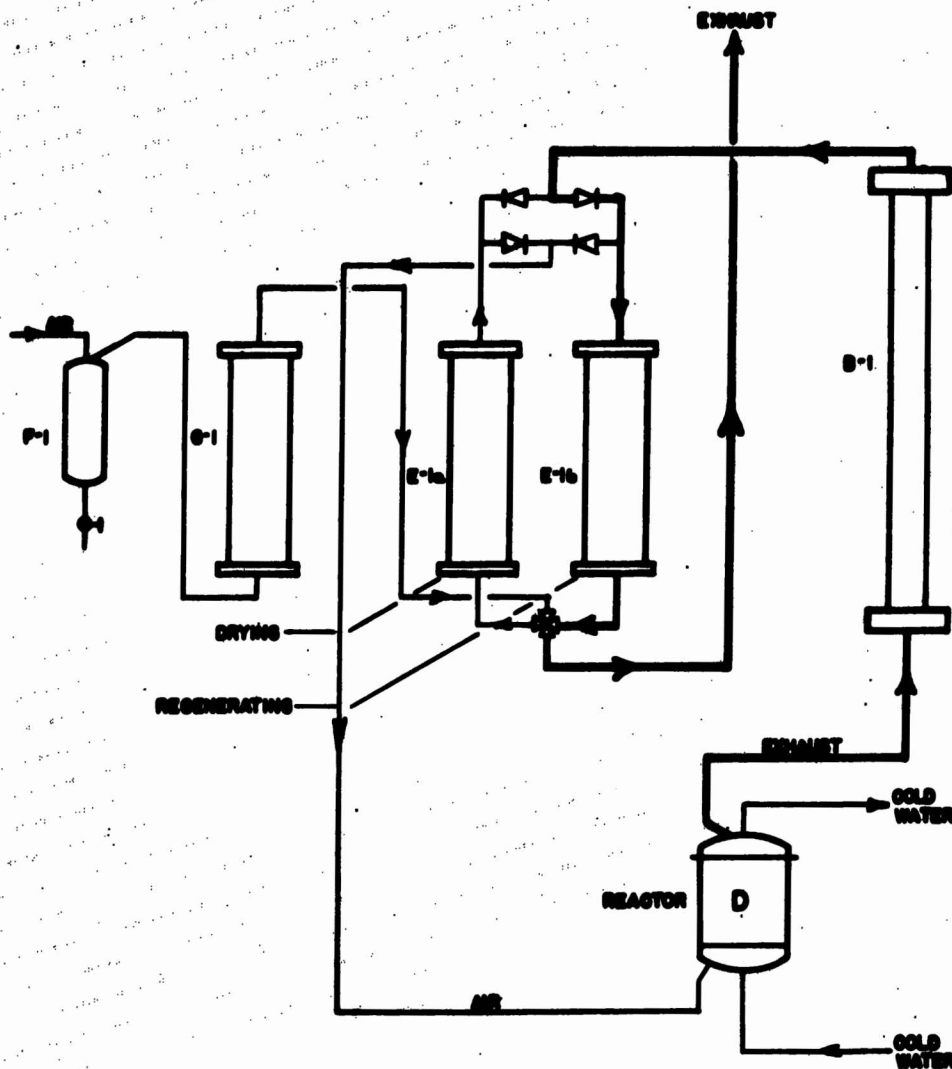
ABSORPTION FLOW SHEET I
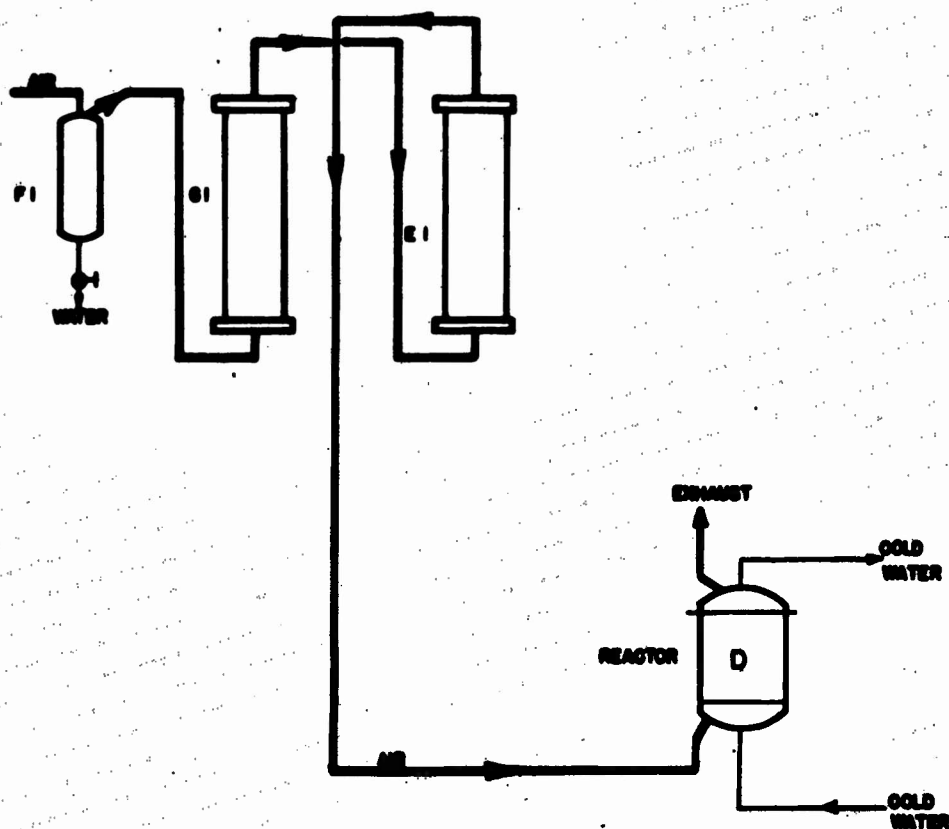
This portion of the flow sheet shows the course taken by the compressed air in passing through the drip drum, oil filter and reactor during an absorption period.   During this time cold water is flowing through the reactor coils.
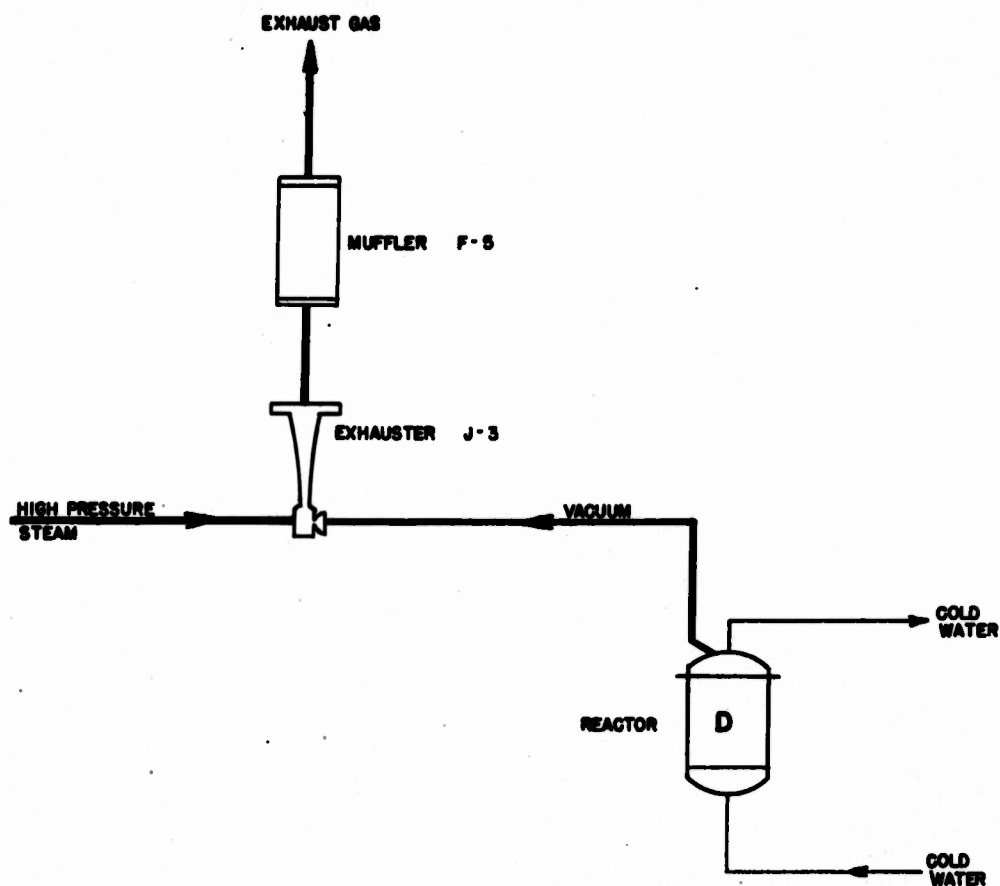
ABSORPTION FLOW SHEET II

In addition to the items shown on Absorption Flow Sheet I, this flow sheet indicates the path of the reactor exhaust gas through the heater and the dryer which is being regenerated.

CONFIDENTIAL

EVACUATION FLOW SHEET

At the end of the absorption period the compressed air is sent to another
reactor, and the reactor which has finished absorption is evacuated by means
of the exhauster as shown above.   Cold water continues to flow through
the reactor coils.

DESORPTION FLOW SHEET

COLD WATER

COOLER C-1

FILTER G-2

DRUM F-2

STORAGE

COMPRESSOR J-2

HOT WATER
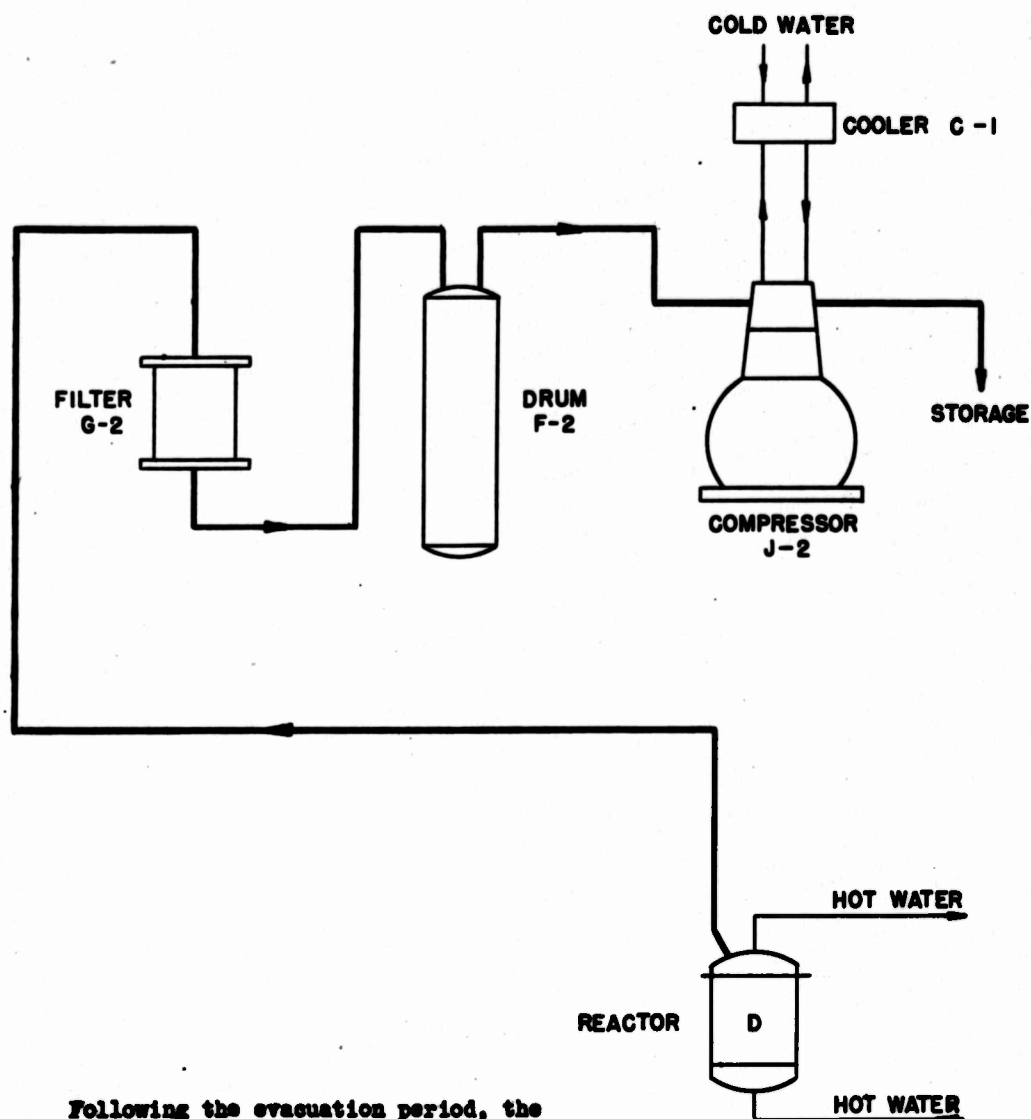
REACTOR D

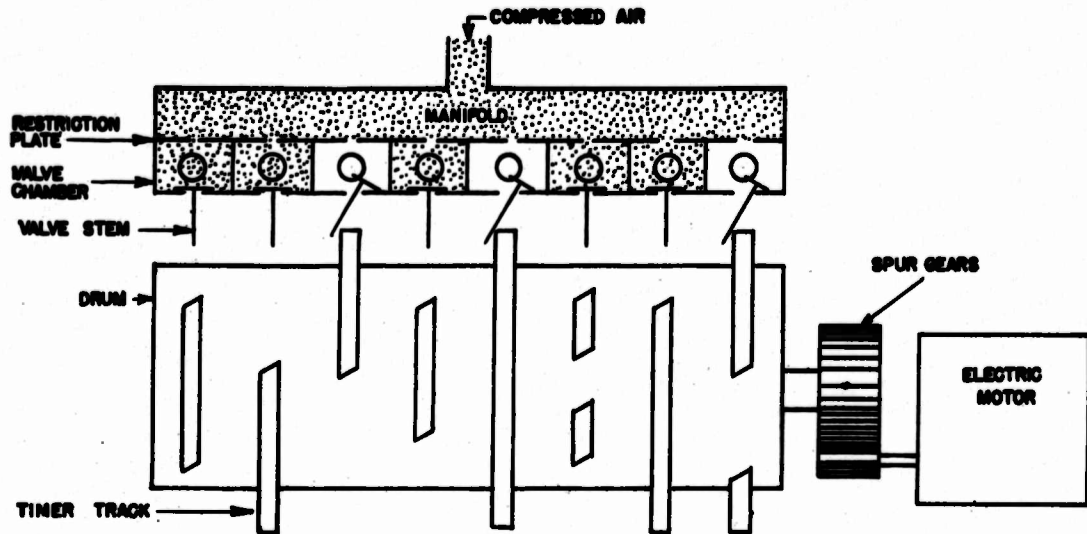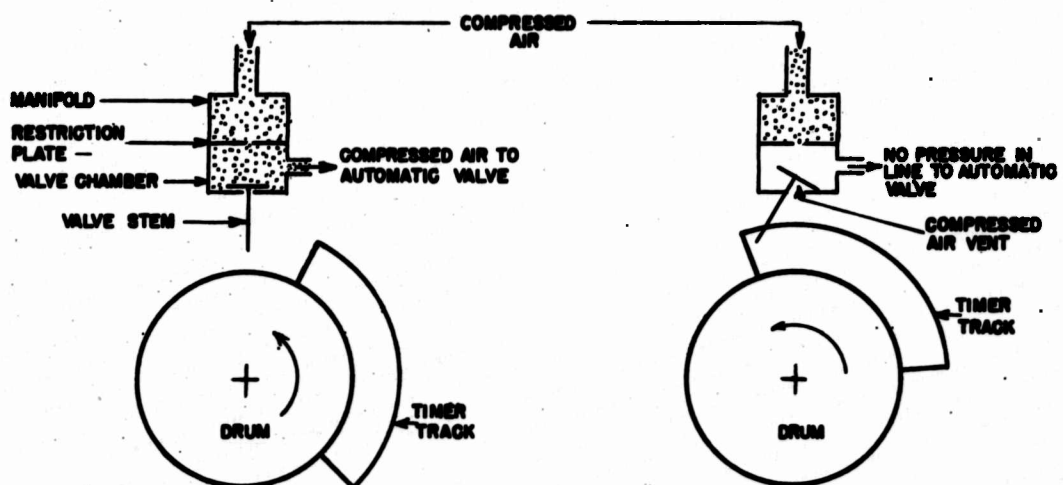HOT WATER

Following the evacuation period, the exhauster is disconnected from the reactor and hot water is sent through the reactor coils. Oxygen is given off and flows through the filter to the drum and the compressor. Here it is compressed and delivered to storage tanks or cutting torches.

AUTOMATIC TIMER

COMPRESSED AIR

MANIFOLD

RESTRICTION PLATE

VALVE CHAMBER

VALVE STEM

DRUM

SPUR GEARS

ELECTRIC MOTOR

TIMER TRACK

FRONT VIEW

COMPRESSED AIR

MANIFOLD

RESTRICTION PLATE —

VALVE CHAMBER

VALVE STEM

COMPRESSED AIR TO AUTOMATIC VALVE

NO PRESSURE IN LINE TO AUTOMATIC VALVE

COMPRESSED AIR VENT

TIMER TRACK

TIMER TRACK

DRUM

DRUM

SIDE VIEW

PIN VALVE SHUT

PIN VALVE OPEN

REEL - C

13 15

A. I. I.

31645

TITLE: Final Report on Oxygen Plant Development (Employing Regenerative Chemicals)

AUTHOR(S): Lobo, Walter E. ; Bockius, C. (Defense Corp.
ORIGINATING AGENCY: Kellogg Co., M. W., Jersey City, N. J. and American Machine
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ABSTRACT:

Xc, OSRD

A description is given of oxygen generating plants utilizing the absorbent "Salcomine". The plants were designed by the M. W. Kellogg Co., and such construction as took place was done by the American Machine Defense Corporation. In addition to a chronological description of each plant or study involved in the program, the report contains a bibliography of correspondence, memoranda, reports and specifications dealing with equipment details and operating experiments. Detailed process calculations and a list of all drawings are supplied for the Shipboard (C-2) unit, the only complete unit fabricated by the contracting companies. Process calculations and detailed designs are not furnished for plants which were studied but not erected.

DISTRIBUTION: Copies of this report obtainable from CADO

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TECHNICAL INDEX

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(23) ✳ oxygen generators

(25) Salcomine

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